日本結晶成長学会パルク成長分科会

第52回研究会資料集

ーSi単結晶と

Si基板上へテロエピタキシャル成長技術ー

共催: ナノ構造・エピタキシャル成長

分科会

日時: 平成14年2月8日(金)

場所: 湘南工科大学東京キャンパス

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on the Formation of Grown-in Defects Nitrogen and Carbon Effect

and Oxygen Precipitation Behavoir

K. Nakal, H. Yokota, J. Takahashi*, A. Tachikawa, K. Kitahara A. Ikari and M. Tanaka R&D Group, Wacker NSCE Corp.

- 1. Introduction
- Grown-in Defects Obserevation **Growth Holding Experiments** 2. Nitrogen-doping Crystals Oxygen Precipitation
- Grown-in Defects Obserevation **Growth Holding Experiments** 3. Carbon-doping Crystals Oxygen Precipitation

Experimental

Diameter

: 150mm and 200mm Resistivity: 8-12 Ocm

: 7-9x10¹⁷atoms/cm² (JEIDA) : 2x10¹³-3x10¹⁶atoms/cm³ Oxygen Nitrogen

measured by SIMS, calculation)

Evaluation As grown

LSTD scanner, BMD analyzer: areal distribution, density, size **FEM: Morphology**

1100°Cx1hr(wet)→Wright Etching **OSF** evaluation

Oxygen precipitation 800°C4hr+1000°C16hr, 700~1100°C 8~128hr →Reduced OI (FTIR), precipitate density (BMD analyzer)

Two Types of Grown-in Defects and OSF

Precipitate Density Dependence

on Heat-Treatment Temperature



in N-Doped CZ-Si

N=5x1014

(after oxidation)

LSTD scanner

(size≥50nm)



Grown-in defects

Void defects (COP)

Defect density :1.8x10/cm³

BMD analyzer

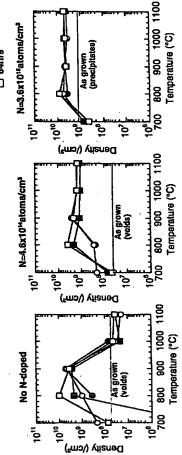
(size≥20nm)

Density

/oid defects & grown-in PPTs

Defect density :1.2x10%cm²





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Summary: Grown-in Defects and Oxygen Precipitation in Nitrogen-Doped CZ-Si

Grown-in defects

Void defects

Size :Decrease with nitrogen concentration Density : Increase with nitrogen concentration

Morphology :platelike tricrinic

-Grown-in oxygen precipitates

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Density : Increase with nitrogen concentration Morphology : Platelet(with strain field)

existence of N and O

Defect regions of nitrogen-doped crystals

V region (Volds), OSF region and I region (Hoops) →Determined by Nitrogen concentration and V/G

Oxygen precipitation

COPY

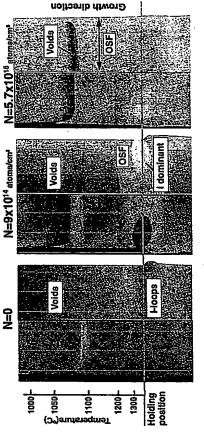
heat-treatment temperature (even in high temp ~1100°C) or time (n=3/2 in Johnson-Mehl Equation) Precipitate density keep constant level regardless of

→thermally stable oxygen nuclel exist

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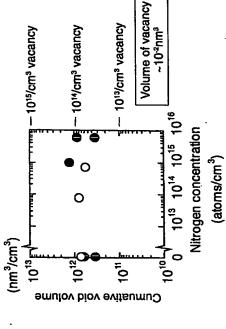
Defect Distribution Change in Growth Held Crystals of Different N Conc.

Holding time: 120min X ray topograph:800°C4hrs+1000°C16hrs

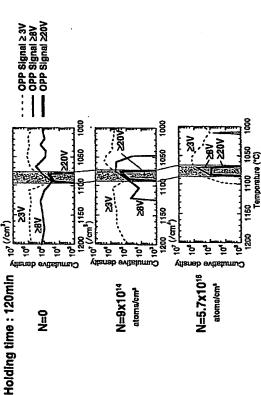


Dependence of Cumulative Void Volume on N Conc.

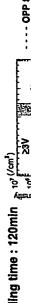
○ Normally grown crystals
 ● Growth holded crystals (120min)







Temperature Dependence of Cumulative Defect Density in growth held crystals of Different N Conc.



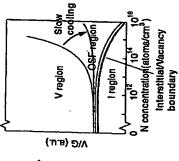
Summary: Growth Holding Experiments of Nitrogen-Doped CZ-SI



-I region shrinks with increase of nitrogen -Volds formed even in OSF region

-Vold formation temperature becomes lower regardless of nitrogen concentration -Total void volume is nearly constant

→thermally stable oxygen nuclei exists -Nitrogen suppress the void growth -Residual vacancies form oxygen clusters Mechanisms



Experimental

Diameter

: 150mm and 200mm

: 8-12 Dcm Resistivity

7-9x10"atoms/cm3 (JEIDA) 3x1014-3x1016atoms/cm3 Nitrogen Oxygen

(measured by SIMS, calculation): 1x10'7atoms/cm³ (JEIDA)

Carbon

Evaluation As grown

Optical Precipitate Profiler (OPP) : Size distribution LSTD scanner, BMD analyzer

1100°Cx1hr(wet)→Wright Etching **OSF** evaluation

Z Z

800°C4hr+1000°C16hr, 700∼1100°C 8-128hr⁴ →Reduced OI (FTIR), precipitate density (BMD analyzer) Oxygen precipitation

'before and after epi-layer growth (>1100°C)

femperature Dependence of Cumulative Defect Density in growth held crystals (C doped and N+C doped)

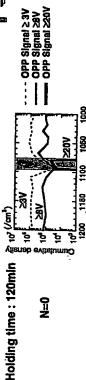
TEM Images of Voids in N-doped, C-doped

and N+C-doped Crystals

C = 1.4 x 1017 atoms/cm³

N = 3 x 10¹⁴ atoms/om²

Without doping



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1100 1050 famperature (°C)

N = 3 x 10¹⁴ atoms/cm³ C = 1.4 x 10¹⁷ atoms/cm³ å







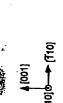








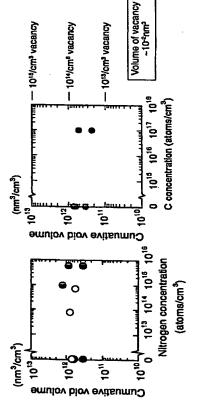






Dependence of Cumulative Void Volume on N Concentration or C Concentration

O Normally grown crystals Growth holded crystals (120min)



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Reduced Oxygen Concentration Dependence

on Heat-Treatment Temperature



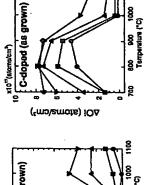
Epitaxial Layer Grownth: >1100°C

N=4.6x1014atoms/cm3

● 8 hrs ■ 16 hrs ▲ 32 hrs ▼ 64 hrs 128 hrs C = 7.3 x 1016 atoms/cm ş C-doped (after epi) x10"(atoms/orr) AOi (atoms/cm³) C = 7.3 x 1016 atoms/cm²

emperature (*C)

AOi (atoms/cm³) N-doped (as grown) Temperature (°C) AOI (atoms/cm²)



Summary: Growth Holding Experiments

of Carbon-Doped CZ-Si

Interstitial/Vacancy region ,0 V region boundary **P**2 V/G (a.u.) -Void formation temperature becomes lower -I region expands with Increase of carbon

regardless of nitrogen concentration

Total void volume is nearly constant

Results

C concentration(atoms/cm³)

becomes lower by Carbon-doping

Inconsistent with the result of

total void volume

-Induced vacancy concentration

Mechanisms

Summary (Nitrogen and Carbon Effects)

Grown-in Defects Formation

Same effect (density→increase, size→decrease)

→different mechanism

N-doping-platelike or rodlike voids

-Defect Region

N-doping shrinks I-region and C-doping expands I-region

N-doping induces stable oxygen nuclei (grown-in precipitates) -Grown-in Oxygen Precipitation

→generate OSF region

Oxygen Precipitation enhancement
-High temperature (1000~1100°C): N-doping (stable nuclei)
-Low temperature (≤800°C)
: C-doping (nucleation by C)

